



EFFECTIVENESS AND COSTS OF DIFFERENT WEED CONTROL METHODS AIMING AT FOREST RESTORATION

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ABSTRACT

Weeds in forest restoration projects can pose significant obstacles to the development of native species seedlings due to their high competitive potential, jeopardizing the success of restoration efforts. In this context, the present study aimed to evaluate the effectiveness of different weed control methods in the seedling vicinity as well as the associated costs of maintaining areas undergoing forest restoration. Six control methods were tested: chemical control using glyphosate herbicide, manual weeding, and three physical control methods using mulch, cardboard, and fiber mats, in addition to a no-intervention control treatment. The experiment was conducted in a randomized block design with five blocks, using the native species *Peltophorum dubium* and *Guazuma ulmifolia*. The analyzed variables included total height and stem diameter of the seedlings at 11 and 24 months after planting as well as the maintenance costs of the area and the control efficiency of each method. The absence of weed control negatively impacted the development of the tested species, both in terms of height and diameter. All control methods proved effective in managing weeds, with no statistically significant differences between treatments for height and diameter increments at 11 and 24 months after planting. Regarding maintenance costs over 24 months for a one-hectare area, the straw mulch method had the lowest cost at R\$ 2,200.00, followed by chemical control (R\$ 2,304.75), manual weeding (R\$ 4,652.16), treated cardboard (R\$ 6,489.80), and fiber bags (R\$ 14,434.80).

Keywords: Weed competition; Recovery; Degraded area

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EFETIVIDADE E CUSTOS DE DIFERENTES MÉTODOS DE CONTROLE DE PLANTAS DANINHAS VISANDO À RESTAURAÇÃO FLORESTAL

RESUMO As plantas daninhas em projetos de restauração florestal podem representar obstáculos significativos ao desenvolvimento das mudas de espécies nativas, devido ao seu elevado potencial competitivo, comprometendo o sucesso dos projetos de recuperação. Neste contexto, o presente estudo teve como objetivo avaliar a eficácia de diferentes métodos de controle de plantas daninhas no entorno das mudas bem como os respectivos custos associados à manutenção de áreas em processo de restauração florestal. Foram testados seis métodos de controle: controle químico com uso do herbicida glifosato, coroamento manual, três formas de controle físico utilizando palhada, papelão e saco de fibra, além de um tratamento sem intervenção. O experimento foi conduzido em delineamento em blocos casualizados, com cinco blocos, utilizando-se as espécies nativas *Peltophorum dubium* e *Guazuma ulmifolia*. As variáveis analisadas incluíram altura total e diâmetro do coleto das mudas, aos 11 e 24 meses após o plantio, além dos custos de manutenção da área e a eficiência de controle de cada método. A ausência de controle de plantas daninhas impactou negativamente o desenvolvimento das espécies testadas, tanto em termos de altura quanto de diâmetro. Todos os métodos de controle mostraram-se eficazes no manejo das plantas daninhas, não havendo diferenças estatisticamente significativas entre os tratamentos para os incrementos em altura e diâmetro, aos 11 e 24 meses após o plantio. No que diz respeito aos custos de manutenção ao longo de 24 meses, para uma área de um hectare, o método de palhada apresentou o menor custo, com R\$ 2.200,00, seguido pelo controle químico (R\$ 2.304,75), coroamento manual (R\$ 4.652,16), papelão tratado (R\$ 6.489,80) e saco de fibra (R\$ 14.434,80).

Palavras-Chave: Matocompetição; Recuperação; Área degradada

1. INTRODUCTION

Forest restoration is a fundamental strategy for recovering degraded areas and is essential for addressing global environmental challenges, including mitigating climate change, contributing to the biodiversity conservation, soil and water resource protection, and the maintenance of essential ecosystem services. These processes aim to restore the structure and the functionality of forest ecosystems, promoting the recomposition of vegetation cover and the resumption of ecological interactions. However, the success of these restoration actions depends on the appropriate management practices, especially in the initial stages of implementation (Toto et al., 2025).

The removal of native vegetation makes areas susceptible to colonization by invasive species, such as grasses of the Poaceae family, including *Melinis minutiflora* (molasses grass) and *Urochloa decumbens* (signalgrass), widely used in pasture formation. These invasive species exhibit high growth and seed dispersal rates, establishing themselves rapidly in degraded areas and competing for essential resources, such as water, light, and nutrients, with native species. This dynamic results in biodiversity loss, reduced natural regeneration potential, and difficulties for ecological restoration processes (Pereira et al., 2015).

Studies show that inadequate weed control in the first years after planting has significant negative impacts on the survival of forest species. This results in high mortality rates and a reduction in dendrometric variables, such as height and stem diameter, compromising the success of reforestation projects (Brancalion et al., 2015).

Several methods can be used to control weeds, including cultural, biological, chemical, mechanical, and physical approaches. The selection of the most appropriate method depends on a number of factors such as regional climatic conditions, site characteristics, and requirements of current environmental legislation. Among the available methods, cultural, chemical, and mechanical methods are the most widely used for weed management. Chemical

control, in particular, is quite widespread in the agricultural and forestry sectors due to its efficiency and ease of application over large areas (Resende & Leles, 2017).

The use of herbicides in forest restoration efforts may be restricted by current environmental legislation. In Conservation Units, such as national parks, the application of herbicides is permitted only in exceptional situations, generally associated with the control of invasive exotic species that pose a risk to natural ecosystems. Furthermore, in Permanent Preservation Areas and Legal Reserves, the chemical management of vegetation is also subject to specific regulations aimed at minimizing environmental impacts and ensuring the conservation of natural resources (ICMBio, 2019). States and municipalities have autonomy to legislate on the use of pesticides, provided that the established regulations are more restrictive than those of federal legislation. An example of this is the state of Santa Catarina, which prohibits chemical weeding in areas such as railway right-of-ways, highways, public roads, streets, sidewalks, avenues, vacant lots, stream banks, and ditches, as established by state law (Santa Catarina, 2009).

According to Silva et al. (2004), among the essential cultural practices for the establishment and the management of forest stands, those that demand the greatest amount of labor are mowing and manual weeding with a hoe, both used in weed control, representing a significant portion of the total investment. In a study carried out by these authors, which evaluated the costs of establishing a eucalyptus plantation in the Cerrado region, it was observed that mowing and crowning activities demanded the greatest amount of labor time, corresponding to 27% of the total time invested, exceeding other activities, such as planting and ant control.

The processes of restoring degraded areas are complex and dynamic. Understanding the perceptions of the various social actors involved, including rural producers, family farmers, traditional peoples, and large companies, is essential for the success of forest restoration interventions, especially considering that their results are perceived in the medium and

long term and that the responsibility for managing these areas falls on these groups. In this sense, identifying viable alternatives for weed control that are suitable for the specific characteristics of each project is fundamental to the success of restoration activities. Given this scenario, the present study aimed to evaluate different weed control methods, in order to provide information on the level of control provided by each technique and on the responses of forest species subjected to different types of management.

2. MATERIAL AND METHODS

The experimental area is located in the southern region of the state of Minas Gerais, at the geographic coordinates 21° 13.802'S and 44° 58.993'W. According to the Köppen climate classification, the region's climate is type Cwb, characterized as a tropical highland, with mild summers. The average annual temperature is 19.6°C, the average annual rainfall is 1,511 mm, the average annual relative humidity is 76.2%, and the total annual evaporation is 901.1 mm (Alvares et al., 2013).

The preparation of the experimental area began with manual mowing of the entire area using a motorized brush cutter. After 30 days, a glyphosate-based herbicide solution was applied to the entire experimental area at a concentration of 1.5 L ha⁻¹, with the spray volume equivalent to 200 L ha⁻¹ with desiccant action. The leaf-cutter ant control was carried out through localized applications of granulated baits, 20 days before planting, and repeated throughout the experiment whenever necessary.

The soil preparation and the seedling planting were carried out manually. The holes were opened with hoes, measuring 20 cm x 20 cm x 30 cm, at a spacing of 2 m x 2.5 m. During the planting of *Peltophorum dubium* (canafistula) and *Guazuma ulmifolia* (mutamba) species, initial fertilization was carried out using 100 g of single superphosphate at the bottom of each planting hole. In addition, the seedlings received topdressing fertilization with 100 g of NPK 20-05-20 per seedling at 6, 12, and 20 months after planting.

Six treatments were tested for weed control, namely:

T0 – Without control: this involves planting seedlings without using any control methods in the area.

T1 – Treated cardboard: This consists of using pizza box-type cardboard measuring 50 cm x 50 cm, treated with copper sulfate, in order to increase the material durability in the field and delay its decomposition. As proposed by Gonçalves et al. (2017), the cardboard was fixed to the ground using steel staples and placed on the soil around the seedlings.

T2 – Fiber bag: This method involves using fiber bags measuring 50 cm x 50 cm, made of 100% natural fiber. The bags were fixed to the ground using steel staples and placed around the seedlings.

T3 – Manual weeding: consists of manual weeding, using a hoe, around the seedlings measuring 50 cm x 50 cm. The weeding was repeated throughout the experiment, whenever necessary.

T4 – Mulch: This consists of using biomass from grass trimmings, arranged in a circular shape around the seedlings, with dimensions of 50 cm x 50 cm. The biomass forms a thick layer around the seedling, but without covering the aerial part.

T5 – Herbicide: This consisted of applying the herbicide glyphosate using a manual backpack sprayer around the seedling, measuring 50 cm x 50 cm, at a concentration of 1.5 L of the commercial product per hectare, with a spray volume equivalent to 200 L ha⁻¹. The application was repeated throughout the experiment, whenever necessary.

The experiment was conducted in a randomized block design with five blocks, each experimental plot consisting of two *Peltophorum dubium* plants and two *Guazuma ulmifolia* plants. A border of a line was established around the experiment.

The evaluations of dendrometric variables, such as height and diameter of *Peltophorum dubium* and *Guazuma ulmifolia* seedlings, were carried out at 11 and 24 months after planting. The height of the plants was measured with a telescopic ruler. At 11 months, the stem diameter was measured with a digital caliper, while at 24 months the diameter was measured using a measuring tape, positioned 1.3 m from the ground (breast height).

To evaluate the efficiency of weed control methods, the methodology of Bellotto et al. (2009) was adapted, which consists of evaluating the soil cover in each plot. Two seedlings per treatment were randomly evaluated, delimiting an area of 50 cm x 50 cm around each seedling. In this area, the aboveground biomass of weeds was collected close to the ground using pruning shears at 11 and 24 months. The samples were stored in paper bags and placed in forced-air circulation ovens at 65°C until they reached a constant weight. The most frequent weed species in the collection area was also identified.

To estimate the investment required for maintaining the forest plantation, input costs and average prices charged by forestry companies in the southern region of Minas Gerais state were evaluated. During the 24-month experimental period, periodic evaluations were carried out in the area. Weed control interventions were carried out whenever the control area around the seedlings (50 cm x 50 cm) had approximately 50% vegetation cover. This assessment was performed visually, considering the proportion of the soil surface occupied by weeds. All interventions were recorded and accounted for.

The average costs of the operations included inputs, daily rates for cardboard treatment, staple making, operational fees, and transportation, with values quoted from local companies in Lavras, Minas Gerais state. Pricing considered an area of one hectare with 2,000 seedlings, including activities such as manual weeding with a hoe and chemical weeding with a backpack sprayer, priced according to the commercial rates in effect in the region.

The data relating to dendrometric variables (height and diameter) were analyzed to verify compliance with the assumptions of the analysis of variance, and the Shapiro-Wilk normality test was performed. The results of the evaluations were subjected to analysis of variance and, when the F-test was significant ($p \leq 0.05$), comparative analysis was applied using the Scott-Knott test, with a 5% significance level of error, using the SISVAR 5.6 software (Ferreira, 2019).

3. RESULTS

The dendrometric evaluations of diameter and height variables, performed after planting, indicated statistically significant differences between the different weed control methods, compared to treatment T0 (absence of weed control), for the species *Peltophorum dubium* and *Guazuma ulmifolia*. The treatment T0, which did not include weed control, showed the lowest values for diameter and height variables at 11 and 24 months, being 0.98 cm and 0.50 m for *Peltophorum dubium* and 1.74 cm and 0.60 m for *Guazuma ulmifolia*. At 24 months, the diameter and height values observed for *Peltophorum dubium* were 6.33 cm and 2.26 m, respectively, while for *Guazuma ulmifolia*, the diameter was 8.16 cm and the height was 2.86 m.

However, the analyses of the diameter and height variables, performed using the Scott-Knott test at a 5% significance level, did not reveal significant differences between the weed control methods employed, for both *Peltophorum dubium* and *Guazuma ulmifolia*. Thus, the physical, chemical, and

mechanical control methods demonstrated equivalent effectiveness in promoting the height and diameter development of the evaluated species (Table 1).

The different weed control methods did not show statistically significant differences among themselves, as shown in Table 2. Thus, the control methods used were efficient in reducing weed infestation levels compared to treatment T0, which did not involve control. The predominant species occupying the soil was *Urochloa* spp., which is consistent with the history of the area, previously used as pasture for many years.

The results obtained indicate that the different types of physical control were effective in managing weeds. In particular, physical techniques have proven to be effective in preventing the germination of photoblastic positive weeds by blocking sunlight from entering the soil, thus hindering the development of these species (Figure 1). However, it was observed that some weeds germinated under the seedlings. This occurred due to small tears and grooves present in the cardboard and fiber bag, which

Table 1. Mean diameter and height of *Peltophorum dubium* and *Guazuma ulmifolia* seedlings at 11 and 24 months after planting as a function of different weed control treatments. Means followed by the same letter in the column do not differ statistically from each other according to the Scott-Knott test at a 5% significance level

Tabela 1. Médias de diâmetro e altura das mudas de *Peltophorum dubium* e *Guazuma ulmifolia* aos 11 e 24 meses após plantio em função dos diferentes controles de plantas daninhas. Médias seguidas de mesma letra na coluna não diferem estatisticamente entre si pelo teste de Scott Knott, a 5% de probabilidade de erro

Treatments	<i>Peltophorum dubium</i>				
	11 Months		24 Months		
	Diameter(cm)	Height(m)	Diameter(cm)	Height(m)	
Treated cardboard	2,96 a	1,27 a	15,40a	5,53a	
Herbicide	2,85 a	0,97 a	15,50a	5,33a	
Manual weeding	2,98 a	0,95 a	13,66a	4,66a	
Mulch	2,10 a	0,83 a	13,13a	4,3a	
Fiber bag	2,63 a	0,92 a	12,50a	4,73a	
Without treatment	0,98 b	0,50 b	6,33b	2,26b	
CV%	13,44	6,41	25,84	15,15	
	<i>Guazuma ulmifolia</i>				
	Treated Cardboard	3,43 a	1,71 a	24,00a	7,16a
	Herbicide	4,14 a	1,78 a	19,83a	6,18a
	Manual weeding	3,79 a	1,56 a	21,83a	6,70a
	Mulch	3,58 a	1,33 a	24,76a	6,66a
	Fiber bag	3,00 a	1,26 a	20,00a	7,03a
	Without treatment	1,07 b	0,60 b	8,16b	2,86b
	CV%	20,31	10,3	14,6	10,77

Table 2. Dry biomass in grams (DB) of weeds collected over the seedlings within a 50 cm × 50 cm area in the different treatments at 11 and 24 months after planting. Means followed by the same letter in the column do not differ statistically from each other according to the Scott-Knott test at a 5% significance level

Tabela 2. Biomassa seca em gramas (MS) de plantas daninhas coletada sobre as mudas nas dimensões 50 cm x 50 cm nos diferentes tratamentos aos 11 e 24 meses após o plantio. Médias seguidas de mesma letra na coluna não diferem estatisticamente entre si pelo teste de Scott Knott a 5% de probabilidade

Treatments	Dry biomass (DB) of the weed plant	
	DB (g) at 11 (eleven) months	DB (g) at 24 (twenty-four) months
Treated cardboard	2,50a	1,17a
Herbicide	3,83a	2,83a
Manual weeding	4,66a	3,66a
Mulch	4,83a	4,00a
Fiber bag	7,00a	11,50a
Without treatment	172,33b	241,83b
CV%	38,63	30,68



Figure 1. Physical weed control using mulch and treated cardboard at 9 months after planting for the species *Peltophorum dubium* (A) and *Guazuma ulmifolia* (B), in contrast to the treatment without weed control for *Guazuma ulmifolia* (C)

Figura 1. Controle físico das plantas daninhas utilizando palhada e o papelão tratado aos 9 meses após o plantio para as espécies *Peltophorum dubium* (A), *Guazuma ulmifolia* (B) em contraste ao tratamento sem controle de plantas daninhas *Guazuma ulmifolia* (C)

allowed the sunlight to penetrate and some weed species to establish themselves (Figure 2).

Mulch cover offers physical and biological control over weeds, reducing soil temperature and keeping it moist, which favors biological activity. This can promote seed deterioration by the action of fungi and insects, contributing to a decrease in the weed population. Correia &

Durigan (2004) report that the application of 5 to 15 tons of sugarcane straw per hectare inhibits the germination of *Brachiaria decumbens*. However, physical control is limited to weeds that would germinate directly under the cover. Climbing species, such as *Ipomoea* spp. and *Neonotonia wightii*, can spread across the ground and damage seedlings as they seek support for their development.



Figure 2. Weed germination under the fiber sack (A) and treated cardboard (B), and the inefficiency of physical control in managing *Neonotonia wightii*, which suppresses *Peltophorum dubium* (C) at 9 months after planting
Figura 2. Germinação de plantas daninhas sob o saco de fibra (A) papelão tratado (B), e ineficiência do controle físico para o controle de *Neonotonia wightii* suprimindo a espécie *Peltophorum dubium* (C) aos 9 meses após o plantio

The cost of forestry operations is a critical factor in budget management planning, regardless of the size of the managed area. Table 3 presents an estimate of the investment required to maintain a forestry experiment over 24 months, considering an area of 1 hectare. During this period, periodic assessments were carried out in the experimental area. Whenever the density of weeds around the seedlings exceeded 50%, control interventions were implemented.

In addition, the frequency of interventions required to ensure effective

weed control in each treatment was analyzed. In chemical control, four applications were carried out in the first year and three in the second year. On the other hand, the manual weeding with a hoe required five interventions in the first year and three in the second one. The other physical treatments required only two interventions, one every 12 months. During the renewal of the physical treatments, all weeds around the seedlings were removed.

The analysis of the costs for weed control revealed that the use of fiber bags had the highest maintenance cost, mainly due to

Table 3. Costs and maintenance frequency using different weed control methods in the first and second years after planting and total cost over 24 months, considering an area of one hectare
Tabela 3. Custos e frequência de manutenção utilizando diferentes métodos de controle de plantas daninhas no primeiro e segundo ano após o plantio e custo total aos 24 meses, considerando uma área de um hectare

Activities	Frequency (1st year)	Cost (R\$/ha) (1st year)	Frequency (2nd year)	Cost (R\$/ha) (2nd year)	Total Cost (R\$/ha) (24 months)
Herbicide	4	1.317,00	3	987,75	2.304,75
Manual weeding	5	2.907,60	3	1.744,56	4.652,16
Treated cardboard	1	3.244,90	1	3.244,90	6.489,80
Fiber bag	1	7.217,40	1	7.217,40	14.434,80
Mulch	1	1.100,00	1	1.100,00	2.200,00

the high purchase price of this material. The adoption of fiber bags as a control method would only be economically viable if the rural producer already had this resource available. To fix the treated cardboard and the fiber bag to the ground, metal staples made from fence wires were used, which allowed the staples to be reused in the second year. This reuse resulted in a reduction in expenses and, consequently, in investments.

The use of treated cardboard was the second most expensive method for weed control. However, there are strategies that can reduce these costs. Gonçalves et al. (2017) and Nagy et al. (2022) suggest, in their methodologies, the use of bamboo staples and the acquisition of cardboard from recycling cooperatives, which can significantly reduce costs. In the Lavras region, MG state, the average price per kilo of cardboard in recycling cooperatives is three (3) Reais, while the cost of each pizza box is around one Real.

In this study, pizza boxes were chosen as treated cardboard in order to maintain scientific rigor. However, if the aforementioned strategies were implemented, the maintenance cost could be reduced by approximately 40%.

4. DISCUSSION

Under the climatic and geographical conditions in which this study was conducted, competition for water, light, and nutritional resources between weeds and forest species is a limiting factor for the development of the species tested in plantings intended for reforestation. This perspective is corroborated by Santos & Silva (2018), who discuss the competitive interactions between weeds and forest species in reforestation areas. Direct competition from weeds with seedlings resulted in a significant reduction in the initial growth of the species *Peltophorum dubium* and *Guazuma ulmifolia*. Therefore, effective weed control in the first two years after the establishment of the forest stand is essential for the success of forest restoration projects.

According to Faria et al. (2018), the species *Cariniana legalis* and *Pterygota brasiliensis* did not withstand direct

competition with weeds during the first 11 months after planting, resulting in the death of all individuals. Maciel et al. (2011) demonstrated that effective weed management provided better initial development of native forest species, highlighting the high sensitivity of these species to competition for resources during the initial development phase.

In another study, Freitas et al. (2022) evaluated the effect of different weed control methods in native species plantations. The results indicated that the use of different types of mulching did not significantly affect the diameter and height of the plants, although the treatments were effective in reducing weed density. Similar results were reported by Gonçalves et al. (2017) in Seropédica, Rio de Janeiro state, when evaluating the growth of forest seedlings subjected to different crowning methods, including manual weeding, and the use of pizza box cardboard. The results showed that there were no significant differences in the increase in seedling height between the two methods.

However, there are neutral and negative photoblastic plants, such as *Ipomoea grandifolia*, *Ipomoea nil*, and *Merremia aegyptia*, that germinate independently of light (Orzari et al., 2013). Cardboard, in addition to blocking light, forms a physical barrier against the growth of plants that germinate beneath it. Given that most weed seeds are small and have limited reserves, it is unlikely that a plant germinating under cardboard will be able to overcome it. Studies conducted by Gonçalves et al. (2017), Neves et al. (2011), and Nagy et al. (2022) corroborate these results, reporting high efficiency in weed control using cardboard as a physical control method.

Among the main advantages of the physical methods tested is the lower need for maintenance throughout the year. In the present study, seven herbicide interventions and eight manual weeding interventions were necessary during the 24-month period. In comparison, the physical control was used only twice in the same period. In hard-to-reach areas or in locations that require longer travel times, the physical control may be a more advantageous alternative. In addition,



periodic controls are subject to variations in the maintenance schedule, which, in case of delays, can intensify competition between seedlings and weeds, increasing maintenance costs. This problem does not occur with the physical control, which offers greater stability.

The manual weeding method resulted in a 50.45% higher cost compared to herbicide control, in addition to requiring a higher frequency of interventions during the first year. However, from the second year onwards, there was a reduction in the need for maintenance for both methods, manual weeding and chemical control. This decrease can be attributed to the development of the canopies and the increase in plant height, which reduced the incidence of light on the soil, thus decreasing the competitive potential of weeds.

Maciel et al. (2011) and Santos et al. (2018), when evaluating the maintenance costs of forest areas, also concluded that the application of herbicides offers a better cost-benefit ratio compared to manual weeding of seedlings. The low cost of the herbicide, its versatility for manual and mechanized application, in addition to the broad spectrum of weed control – encompassing both broadleaf and narrowleaf species – make glyphosate the most widely used herbicide worldwide in forestry and agriculture (Benbrook, 2016; Maqueda et al., 2017).

In a study that analyzed the necessary frequency of chemical weeding and manual mowing activities for conducting forest restoration, Santos et al. (2018) observed that the costs of interventions were higher in the first year, a period in which native species are more susceptible to competition. In addition, the authors highlighted that chemical control not only has a lower cost compared to manual mowing, but also requires less labor, making it a more efficient option for long-term maintenance.

Finally, physical control with straw mulch presented the lowest cost among the methods evaluated for weed control, being 52.71% less expensive than manual mowing and 4.54% more economical than chemical control. The use of straw mulch as a method of weed control is widely adopted in agricultural plantings, being one of the fundamental practices of minimum tillage

techniques. Silva Neto et al. (2018) report that 15 tons per hectare of straw mulch cover is sufficient to form a layer of approximately 15 cm, hindering the germination of weeds. The authors also note that between 6.5 and 7.4 tons per hectare of sugarcane straw is already sufficient to inhibit the emergence of certain weed species.

At first glance, from both an economic standpoint and in terms of weed control efficiency, the use of crop residue appears to be a viable solution for area management. However, this method has some limitations, such as the availability of sufficient biomass to cover the area, as well as challenges related to the collection and transport of the residue, which can increase costs and, consequently, make the method economically unfeasible.

5. CONCLUSION

All the control methods tested, when compared to treatment without weed control, demonstrated effectiveness, with no significant differences between them in the average height and diameter of *Peltophorum dubium* and *Guazuma ulmifolia* seedlings.

The method with the lowest maintenance cost was the use of mulch, followed by herbicide control, manual weeding, and treated cardboard, with the use of fiber bags being the most expensive.

The physical controls tested are technically viable alternatives to replace both mechanical and chemical control, offering similar effectiveness in weed control compared to the other treatments. However, the viability of using mulch depends on the availability of this material in the area, which may limit its application.

The treated cardboard, in turn, presents a potential for cost reduction, especially with the purchase of the material from recycling cooperatives and the use of bamboo staples for fixation, which can improve the cost-benefit ratio of this control method.

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AUTHOR CONTRIBUTIONS

Souza, L. R.: Conceptualization, Data Curation, Research, Project Administration, Visualization, Writing – Original Draft, Writing – Review & Editing; Souza, A. N.: Data Curation; Research; Botelho, S. A.: Conceptualization, Project Administration, Supervision, Writing – Review & Editing; Melo, L. A.: Conceptualization, Methodology, Validation; Gama, A. T.: Formal Analysis, Writing – Review & Editing; Almeida, R. S.: Formal Analysis, Writing – Review & Editing.

DATA AVAILABILITY

The entire dataset supporting the findings of this study has been published within the article.

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